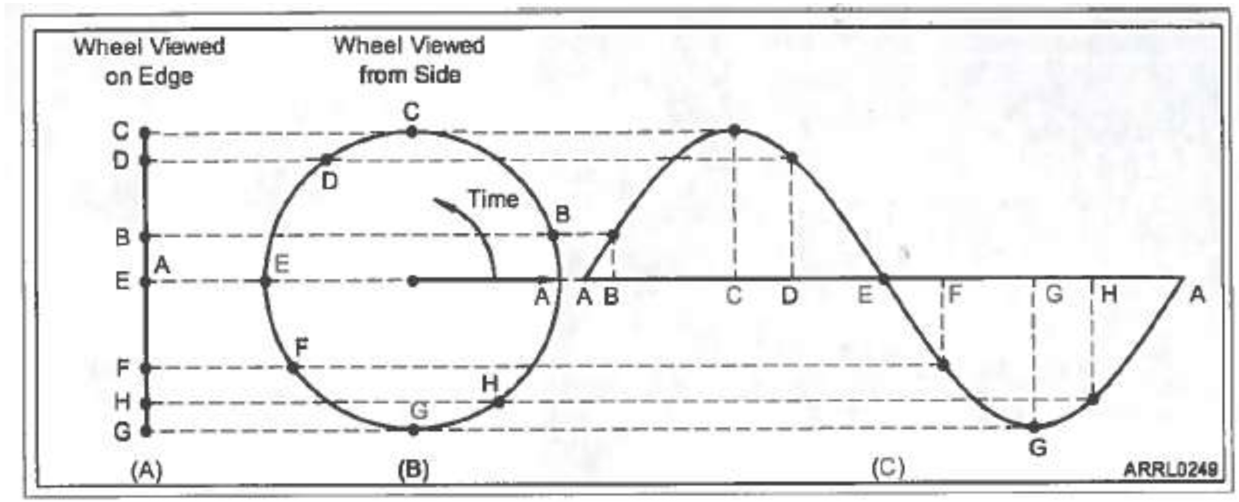
Chapter 7
Radio Signals and Measurements

Types of AC Waveforms – Sine



- Most fundamental waveform
- Also describes rotating motion
- A = sin(θ)
- 2 π radians = 360 degrees

- $f = \frac{1}{T}$ and $T = \frac{1}{f}$

T = time to complete 360 degrees

f = frequency

Types of AC Waveforms - Complex

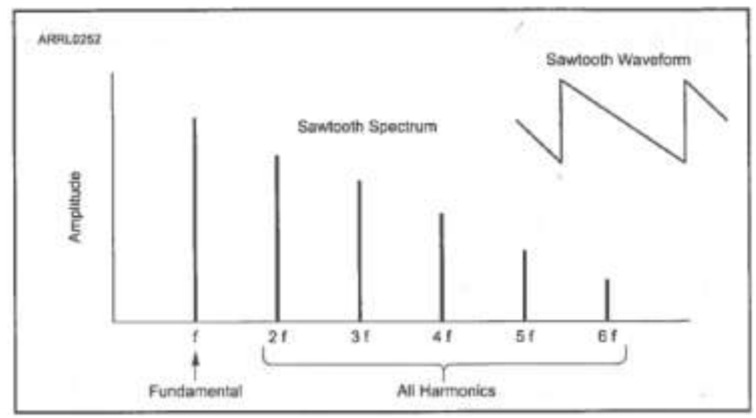
Complex Waveforms

- Signals composed of more than one sine wave
- Telephone keypads – dual-tone multi-frequency (DTMF)
- regular waveforms
  - made up of a sine wave and its harmonics
  - resulting waveform has single overall frequency
  - Lowest frequency sine wave is called the fundamental
- Irregular waveform
  - Made up of sine waves NOT harmonically related
  - Human speech

Complex Waveforms

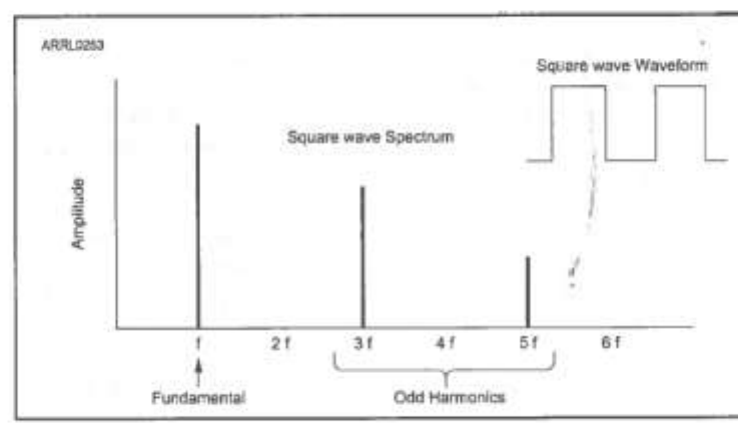
Sawtooth Waves

- Sine wave at its fundamental frequency
- plus all of its harmonics
- Ramp waveform is reverse

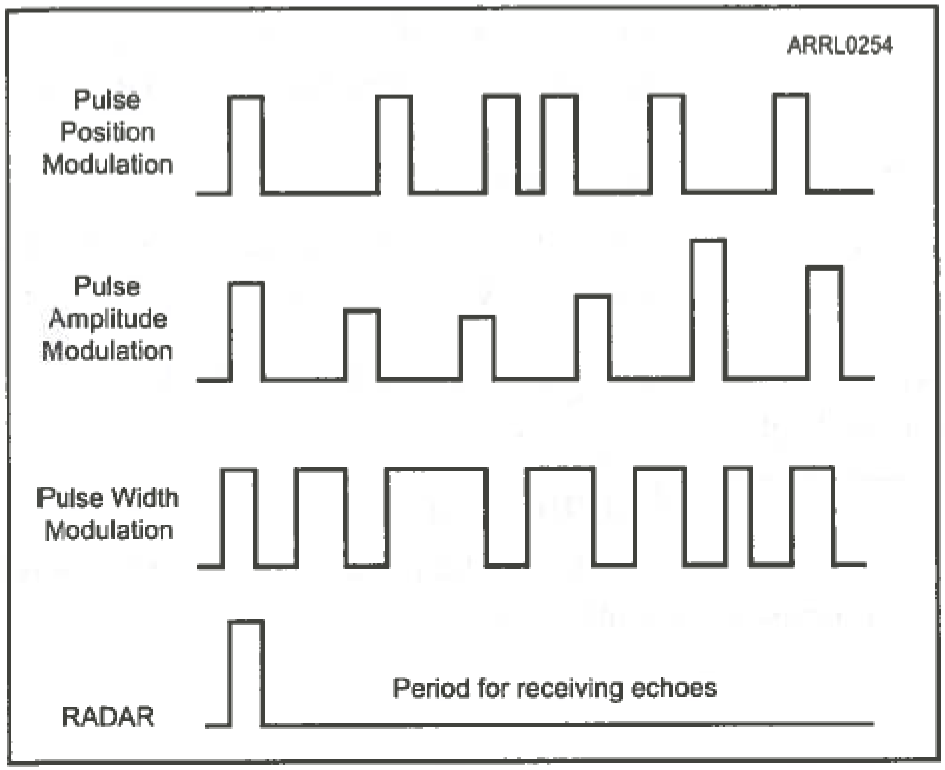


Square Waves

- Sine wave at its fundamental frequency
- plus all of its odd harmonics

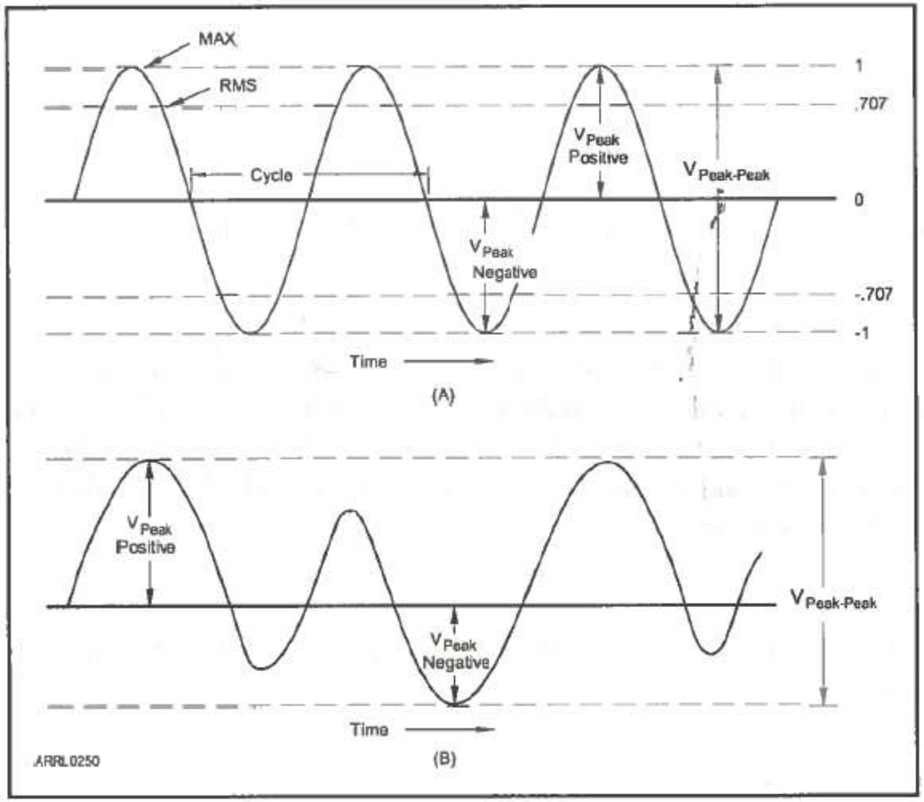


Pulse Waveforms



- Consist of narrow bursts of energy, followed by periods of no signal
- Used to transmit information by varying amplitude, rate, width or position

AC Measurements



- For symmetrical waveforms, $V_P = \frac{1}{2} V_{P-P}$
- $V_{RMS} = .707 \; * \; V_P$
- the dc voltage that would cause an identical amount of heating to the ac peak voltage (V_P)

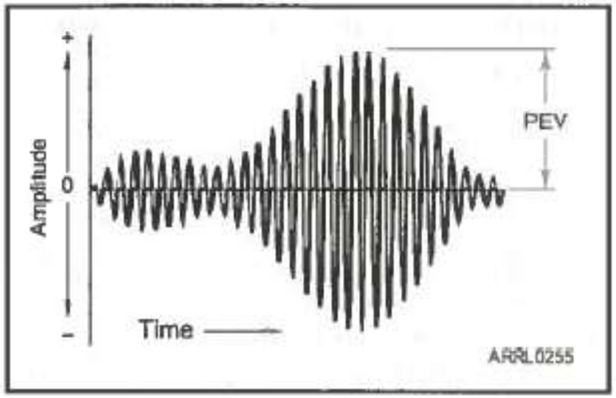
AC Measurements for Sine and Square Waves

	Sine Wave	Square Wave
Peak-to-Peak	2 x Peak	2 x Peak
Peak	0.5 x Peak-to-Peak	0.5 x Peak-to-Peak
RMS	0.707 X Peak	Peak
Peak	1.414 x RMS	RMS
Average	0 (full cycle)	0 (full cycle)
	0.637 x Peak (half cycle)	0.5 x Peak (half cycle)

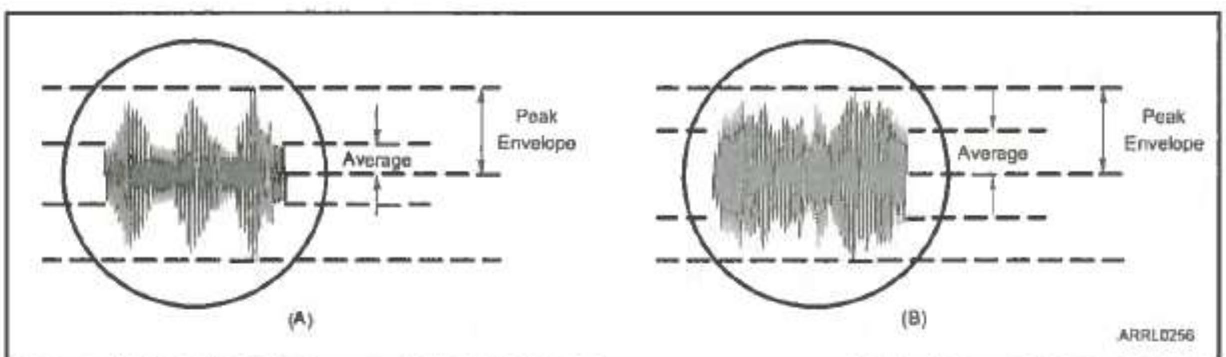
AC Power

- $P_{AVG} = V_{RMS} * I_{RMS}$
- $P_{PEAK} = V_{PEAK} * I_{PEAK} = 2 * P_{AVG}$
- $P_{AVG} = \frac{{V_{RMS}}^2}{Z}$

AC Power

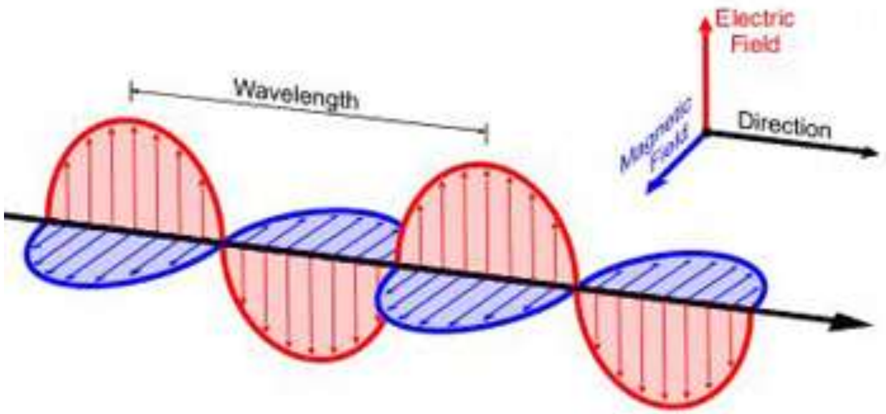


- Peak envelope voltage (PEV) is used to determine power of a complex waveform
- $PEP = \frac{(PEV * 0.707)^2}{R_{LOAD}}$



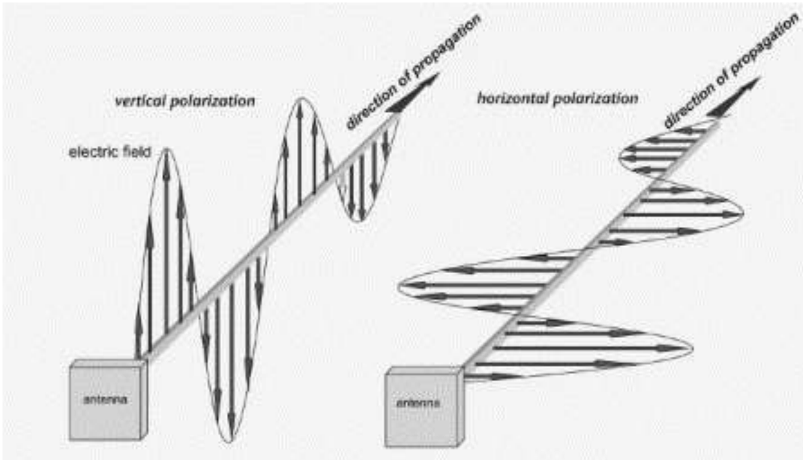
Electromagnetic Waves

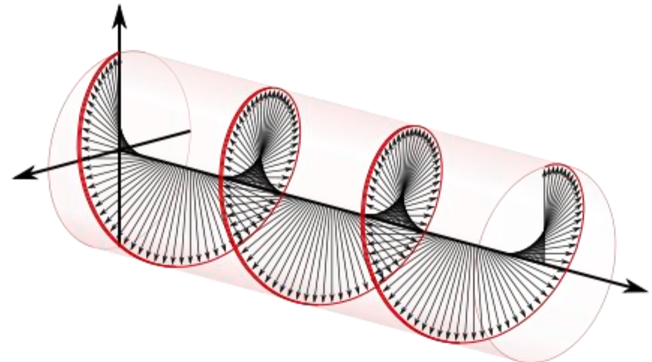
Composed of Electric and Magnetic fields that move through space independently of any component or conductor



- The fields cannot be separated
- The energy in the wave can be detected as either electric or magnetic force
- The fields are created as a single entity (electromagnetic wave) by the motion of electrons in the transmitting antenna

Polarization

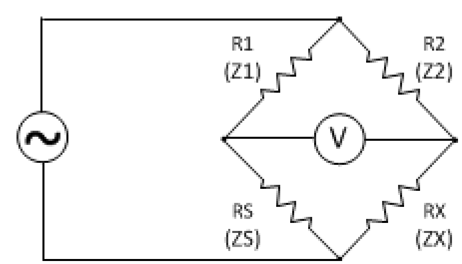




- Orientation of the electric field determines polarization of the wave
- Transmitting antenna's orientation determines wave's polarization
- Vertical – electric field is perpendicular to the Earth
- Horizontal – electric field parallel to surface of the Earth
- Circular

Test Equipment

- Multimeters, Volt-Ohm-Milliammeter (VOM), Voltmeter
  - Accuracy defined as ± X% of full scale
  - Meter sensitivity specified in ohms-per-volt ($^{\Omega}/_{V}$)
- Dip Meters
  - Used to measure circuit frequency, resonant frequency, inject freq into circuit
  - Coupling should be as loose as possible to prevent loading/reducing accuracy
- Impedance Bridges
  - Works by balancing the two voltage dividers
  - Used to measure SWR



Test Equipment

- Frequency Counters
  - Counts number of cycles per second of a signal
  - Accuracy is determined by the quality of its reference crystal and expressed in parts per million (ppm)
  - $Error\ (in\ hz) = \frac{f\ (in\ Hz) * counter\ error\ (in\ ppm)}{1{,}000{,}000}$
- Oscilloscope
  - Used to observe/measure high-speed and complex waveforms
  - Specified in terms of (vertical amplifier) bandwidth
  - Screen grid; Vertical ($^{volts}/_{division}$) & Horizontal ($^{time}/_{division}$)
  - Keep ground connection short as possible
  - Adjust probe compensation with reference square wave (per scope user manual)

Test Equipment

- Oscilloscopes operate in the Time domain
  - Display signal's amplitude versus time
  - Horizontal (x) axis represents time $\left({}^{time}/_{division}\right)$
  - Vertical axis calibrated in volts per division
- Spectrum Analyzer operate in the Frequency domain
  - Display signal's amplitude versus frequency
  - Horizontal (x) axis represents frequency $\left({}^{frequency}/_{division}\right)$
  - Vertical axis normally calibrated in dB per division

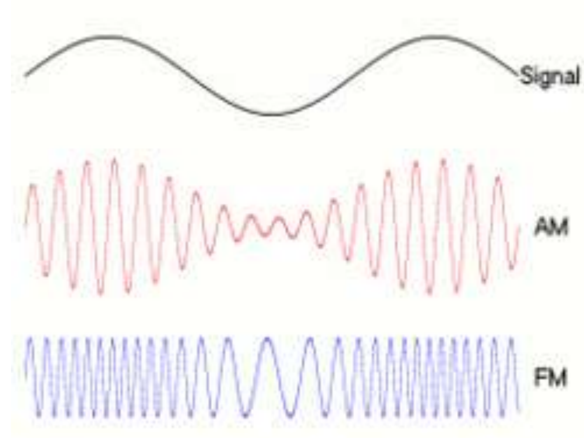
Uses for Spectrum Analyzers

- Use where the frequency content of a complex signal is of primary importance (i.e. amplifiers, oscillators, detectors, mixers, filters, etc.)
- Check the output from a transmitter or amplifier for signal quality
  - Remember to attenuate the signal level to the analyzer to typically 10 mW or less
- Check SSB for two-tone intermodulation distortion (IMD)
- Measure isolation between input and output ports of a 2 meter duplexer

Modulation Systems

Adding and later recovering information from radio frequency signals.

- Amplitude Modulation
- Frequency Modulation
- Phase Modulation
- Pulse Width Modulation



FCC Emission Designations

- International Telecommunication Union (ITU) identifiers
- May be up to 5 characters but 3 is common
- Common in Amateur Radio:

N0N – Unmodulated carrier	F3E – FM telephony
A1A – CW	G3E – Phase modulated telephony
A3E – AM, DSB, Full carrier telephony	F1B – FSK RTTY
J3E – AM, SSB, suppressed-carrier telephony	F2B – AFSK RTTY
J3F – AM, SSB, suppressed-carrier television	F1D – FM data

FM/PM Modulation

- Signal frequency varies at the rate of the modulating-signal frequency
- Amount of frequency change is proportional to modulating signal amplitude = ***deviation***
- ***Deviation Ratio*** = ratio of max deviation to highest modulating frequency
  - Constant for a given transmitter/modulator

Modulation Index

- Ratio of maximum signal frequency to instantaneous modulating frequency

$$MIndex = \frac{D_{MAX}}{m} = \frac{\text{peak deviation hz}}{\text{instant modulating frequency hz}}$$

- Frequency modulator – MIndex inversely proportional to modulating frequency
- Phase modulator – MIndex constant regardless of modulating frequency
- <u>FCC Limits MIndex to maximum of 1.0</u>

Pulse Modulation

- Transmitting analog information as a series of pulses; on/off pulses = 1/0 digital signal so considered digital data
- Pulse-width modulation
- Pulse-position modulation
- Pulse-amplitude modulation
- Used for R/C control and switching power supplies

Multiplexing

- Combining more than one stream of information into one modulated signal
- Frequency division (FDM) multiple subcarriers
- Time division (TDM) interleaving two or more signals into discrete time slots
- Not to be confused with multi-carrier digital modes which interleave a single signal across multiple carriers to increase transmission speed

Interference and Noise

- Interference/QRM – signals that have characteristics of transmitted signals
  - Usually “manmade”, arc welder, CFLs, electric motors
- Noise/QRN – random natural sources or unintentional generation by non-transmitting equipment
  - Usually “natural” i.e. static crashes from lightning

Intermodulation

- Intermodulation (IMD) – multiple frequencies mixed in a non-linear manner
  - Transmitter IMD, nearby transmitted signals mixed in the PA of a transmitter and thus retransmitted
    - Commercial sites may use circulators to eliminate
  - Receiver IMD, strong received signal causes front end to go non-linear and may mix other undesired signals producing spurious received signal
    - Good receiver dynamic range is important to mitigate

Static & Noise

- Static from lightning is especially common on HF bands and can sometimes be heard much higher
- With good propagation it is possible to hear static from lightning on the other side of the world on medium HF frequencies
- Precipitation picking up a charge as it falls can cause rain or snow static

AC Line Noise

- Unfortunately one of the more common forms of QRM (manmade)
  - Caused by arching between electrical conductors or electrical leakage across an insulator that is breaking down
  - Caused by small motors with brushes
  - Light Dimmers, motor speed controls

Locating QRN & QRM Sources

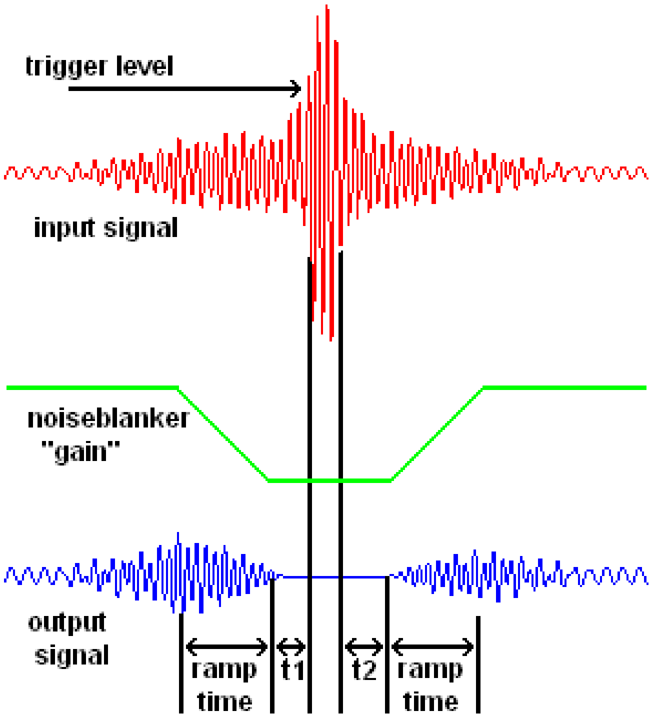
- Process of elimination
  - Run your receiver off battery and shut off main breaker to your house
    - Noise went away; it’s in your house; shut off all circuit breakers, main back on, turn on circuit by circuit till noise comes back, then start turning off/unplugging devices on that circuit
    - Noise stayed; it’s not in your house; more work required, portable AM receiver can be used to track down in some cases

Automotive Noise

- Ignition Noise – make sure the ignition components are in good condition and making secure connection
- Charging system – radio powered direct from battery may help, make sure battery is in good condition, radio and antenna properly grounded
- Instruments – bypass capacitor on sender/motor

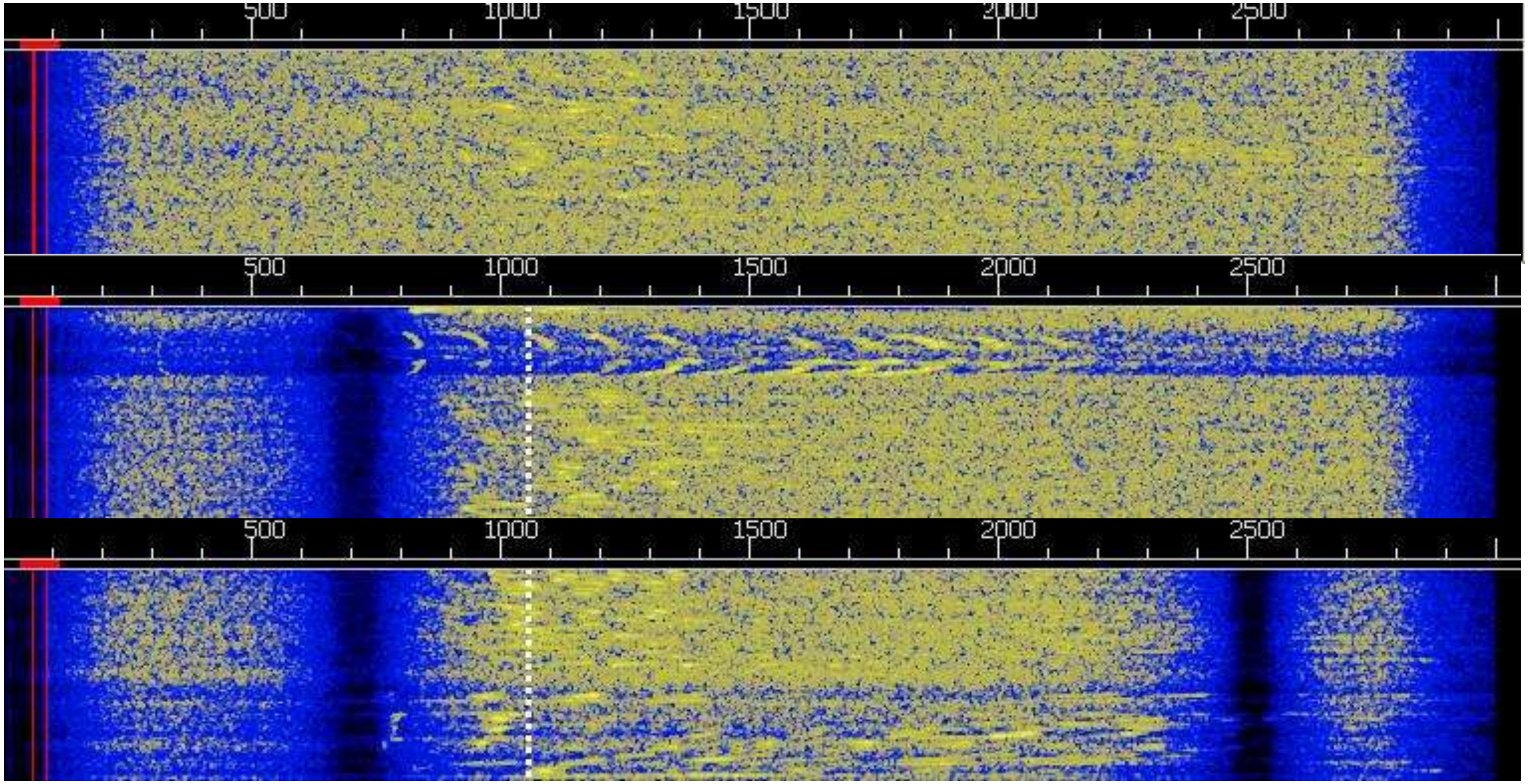
Electronic Noise Reduction

- Do NOT use with Digital Modes!
- Noise Blanker – shuts off signal for short duration “blanking” noise; good for impulse noise



Electronic Noise Reduction (cont.)

- DSP – electronic filter that adapts to noise pattern and eliminates it; especially good for notch filters



Questions